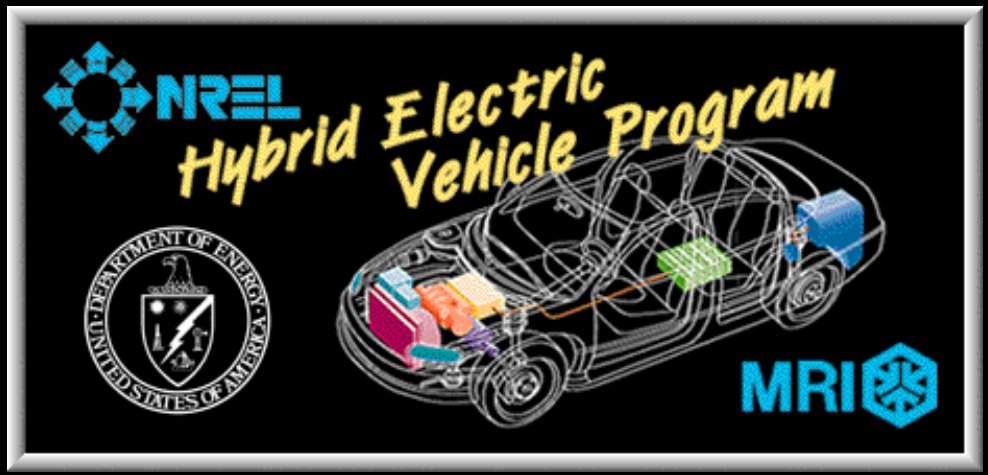
Vehicle Systems Modeling Using ADVISOR *Overview and Project Examples*

Systems Analysis Team

Last updated 8/14/98

Presentation Outline

- Background on NREL & CTTS
- Introduction to ADVISOR
- Demonstration
- Applications
- Future Plans



National Renewable Energy Laboratory

Focused on Renewable Energy and Energy Efficiency

Center for Transportation Technologies and Systems

- Vehicle systems analysis
- Systems-level vehicle modeling
- Alternative fuels R&D
- Vehicle demonstration and testing
- Information dissemination
  - Alternative Fuels Data Center (www.afdc.doe.gov)
- Atmospheric reactions
- Auxiliary loads reduction
- Battery thermal management

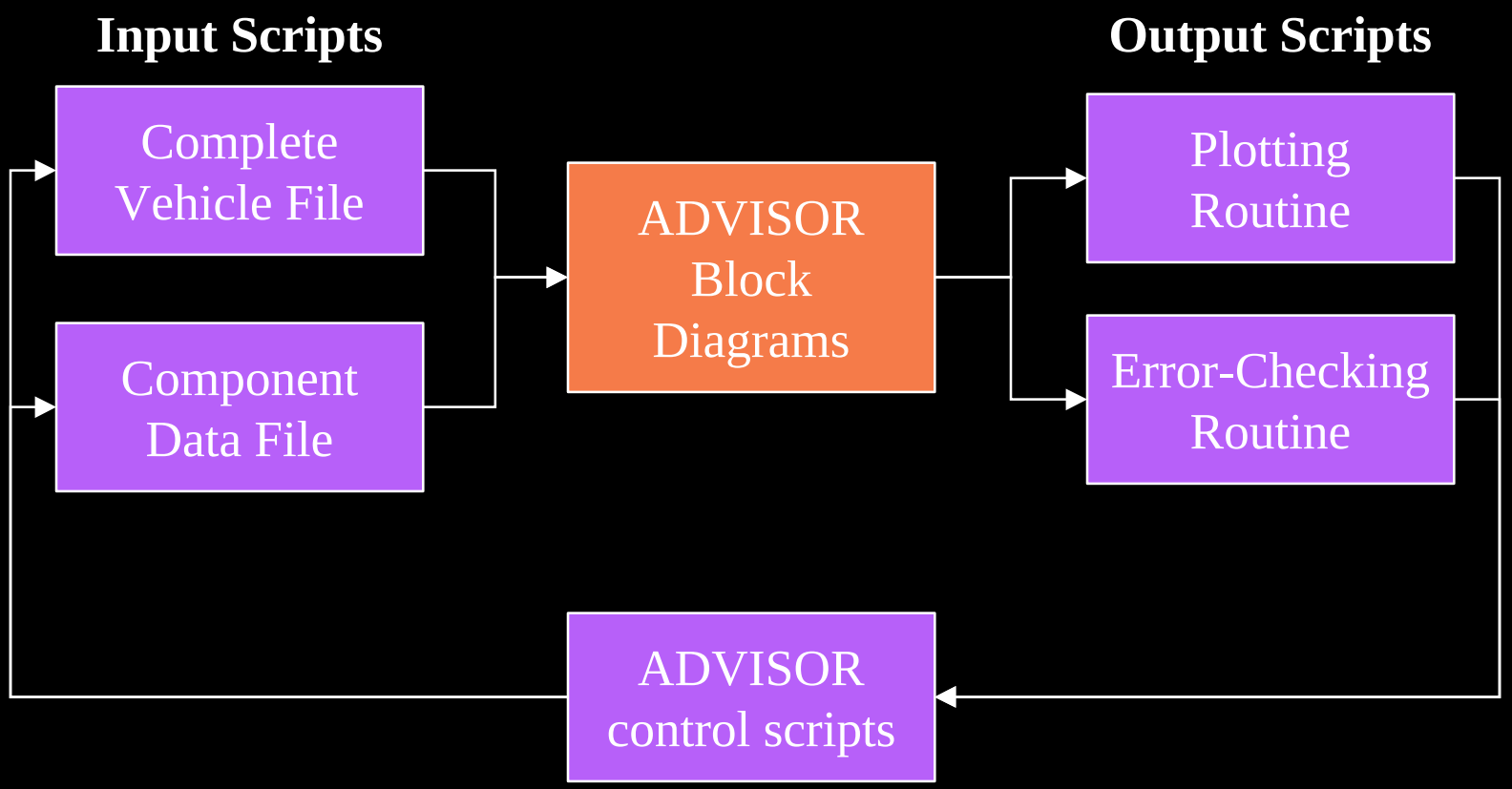
Overview of ADVISOR

- ADVISOR: ADvanced VehIcle SimulatOR
  - used to simulate conventional, electric, or hybrid vehicles
- ADVISOR was created in Nov., 1994 to support DOE Hybrid Program at NREL
- Programmed in MATLAB/Simulink environment
  - graphical/object-oriented environment
  - allows flexibility in modeling new vehicles and control strategies
- Currently used by over 30 organizations
- Continuously fed up-to-date component test data through users and university validation efforts
- Part of a larger systems analysis effort from NREL and DOE

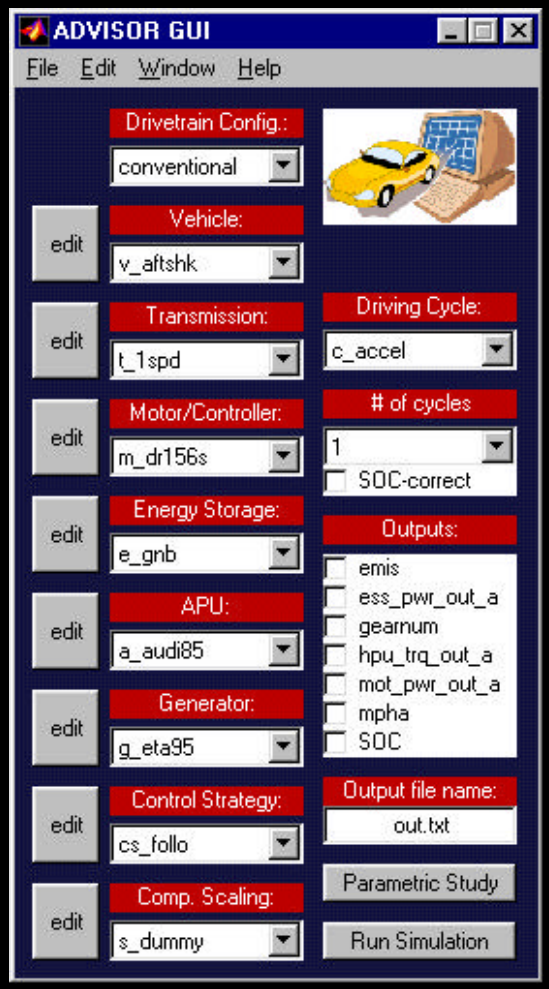
ADVISOR Partners

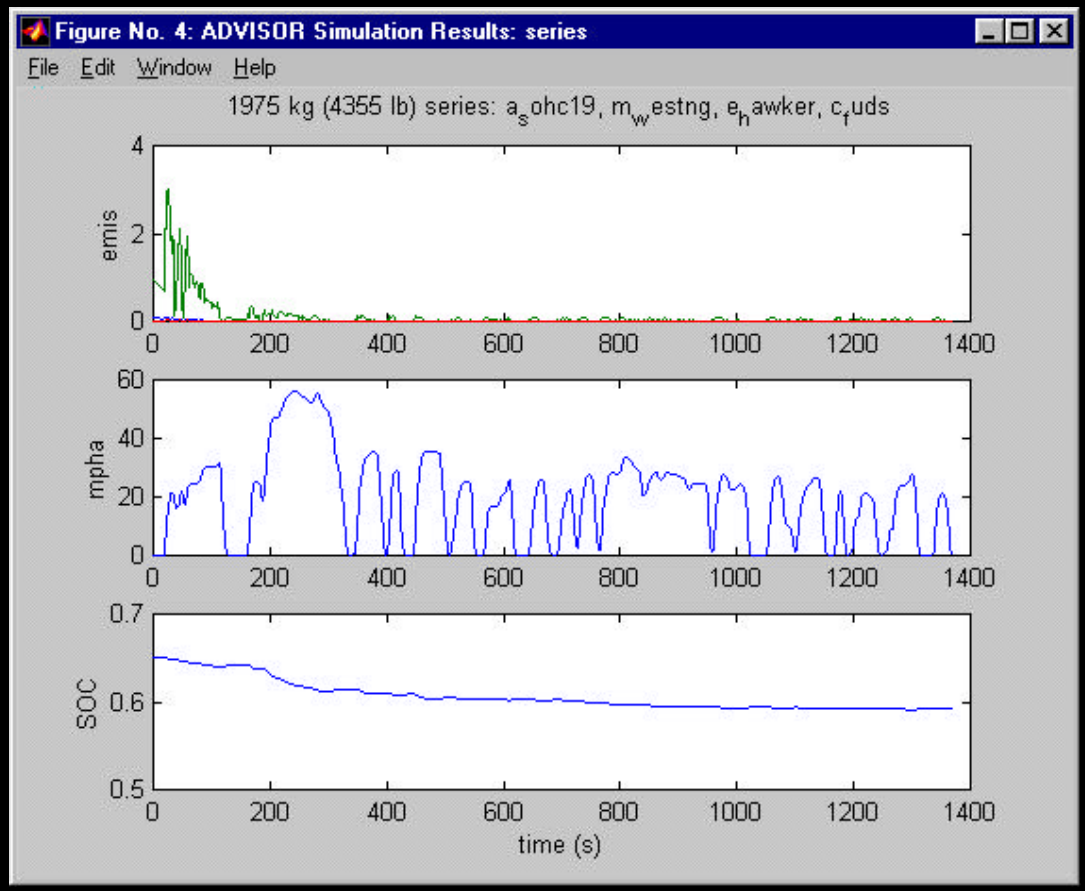
- Argonne National Laboratory
- Dept. of Energy
- Delphi Automotive
- Chrysler Corporation
- Ford Motor Company
- General Motors
- Idaho National Engineering Lab.
- Naval Research Lab.
- Oakland Univ.
- Purdue Univ.
- Princeton Univ.
- Rocky Mountain Institute
- TransMotive Inc.
- Univ. of Illinois at Urbana-Champaign
- Univ. of Maryland
- Univ. of Michigan
- Univ. of Tennessee
- USCAR
- Univ. of California at Davis
- Virginia Tech.
- more...

ADVISOR's File System

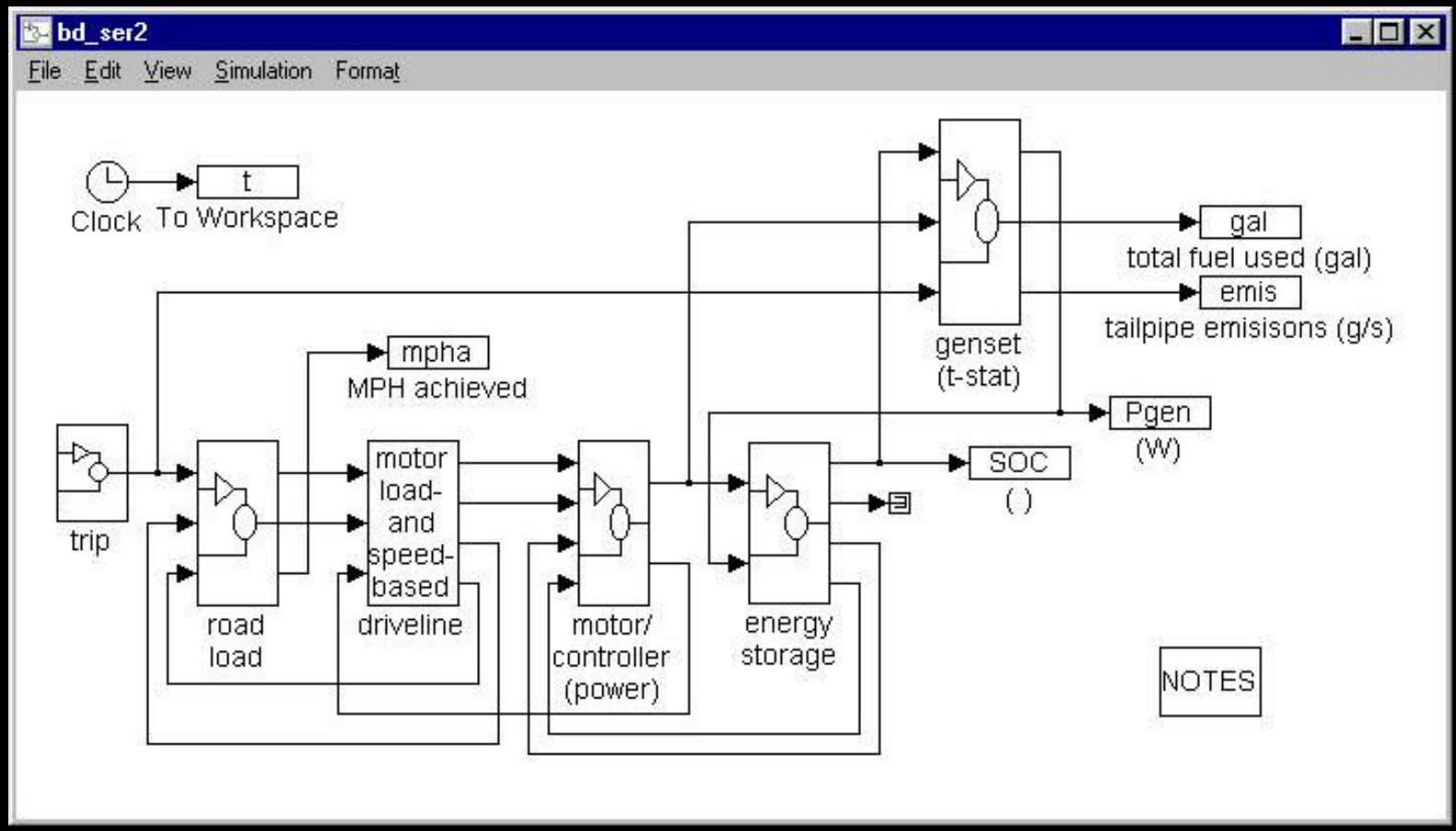


1st Generation ADVISOR GUI (ver. 1.2.1)

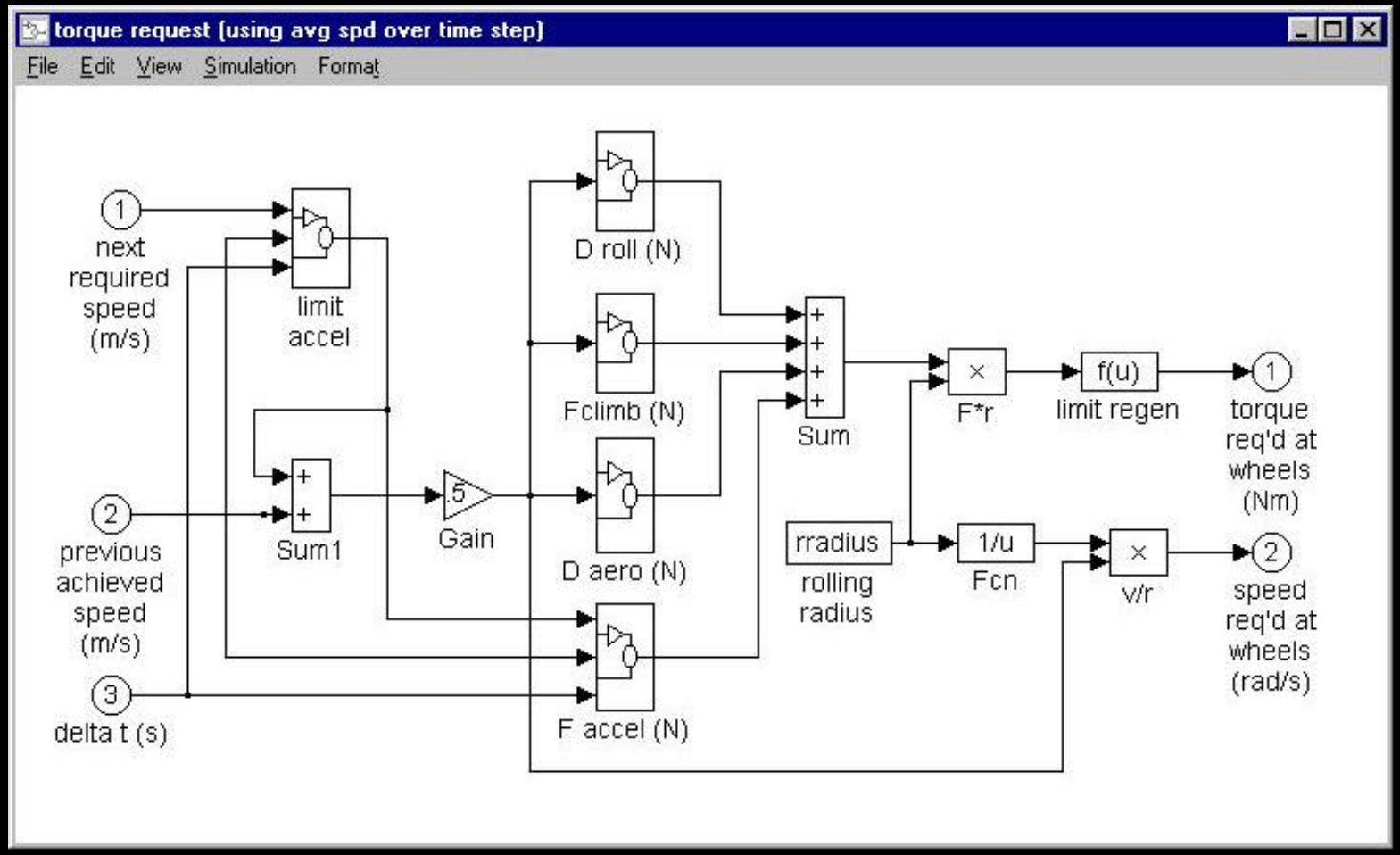




1st Generation ADVISOR Top-Level Block Diagram



1st Generation ADVISOR
2-Layers Down in 'road load'

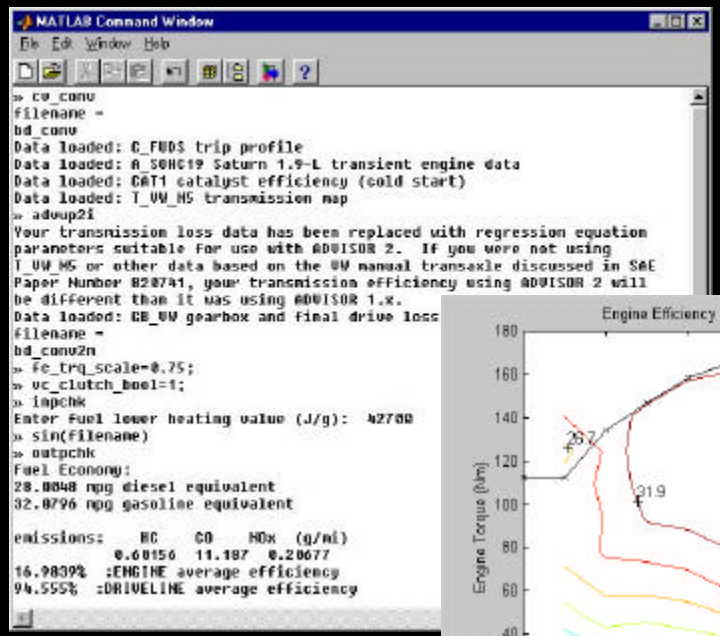


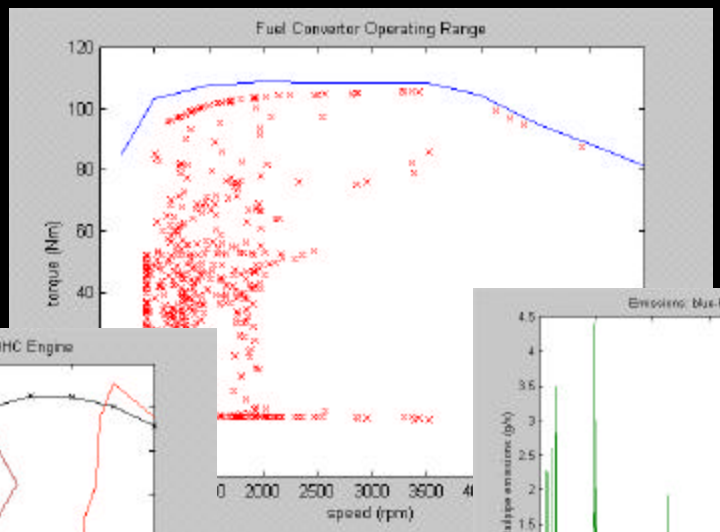
Capabilities of ADVISOR

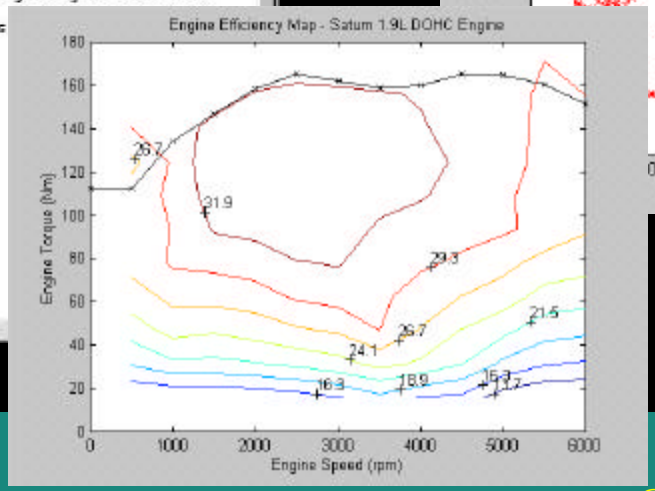
- Various vehicle types
  - conventional, series hybrid, and parallel hybrid vehicles
- Various control strategies
  - thermostat, power follower, power assist, etc.
- GUI or batch mode operation
- Parametric studies
- Performance assessments
- Trade-off studies
- Evaluating new technologies

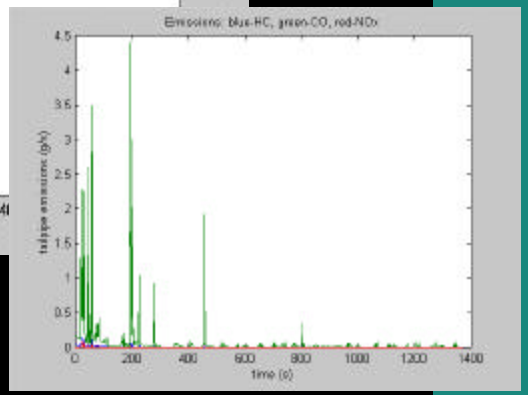
ADVISOR Outputs

- average fuel economy & emissions
- time-dependent plots of variables
- scatter plots: regions of operation within component maps

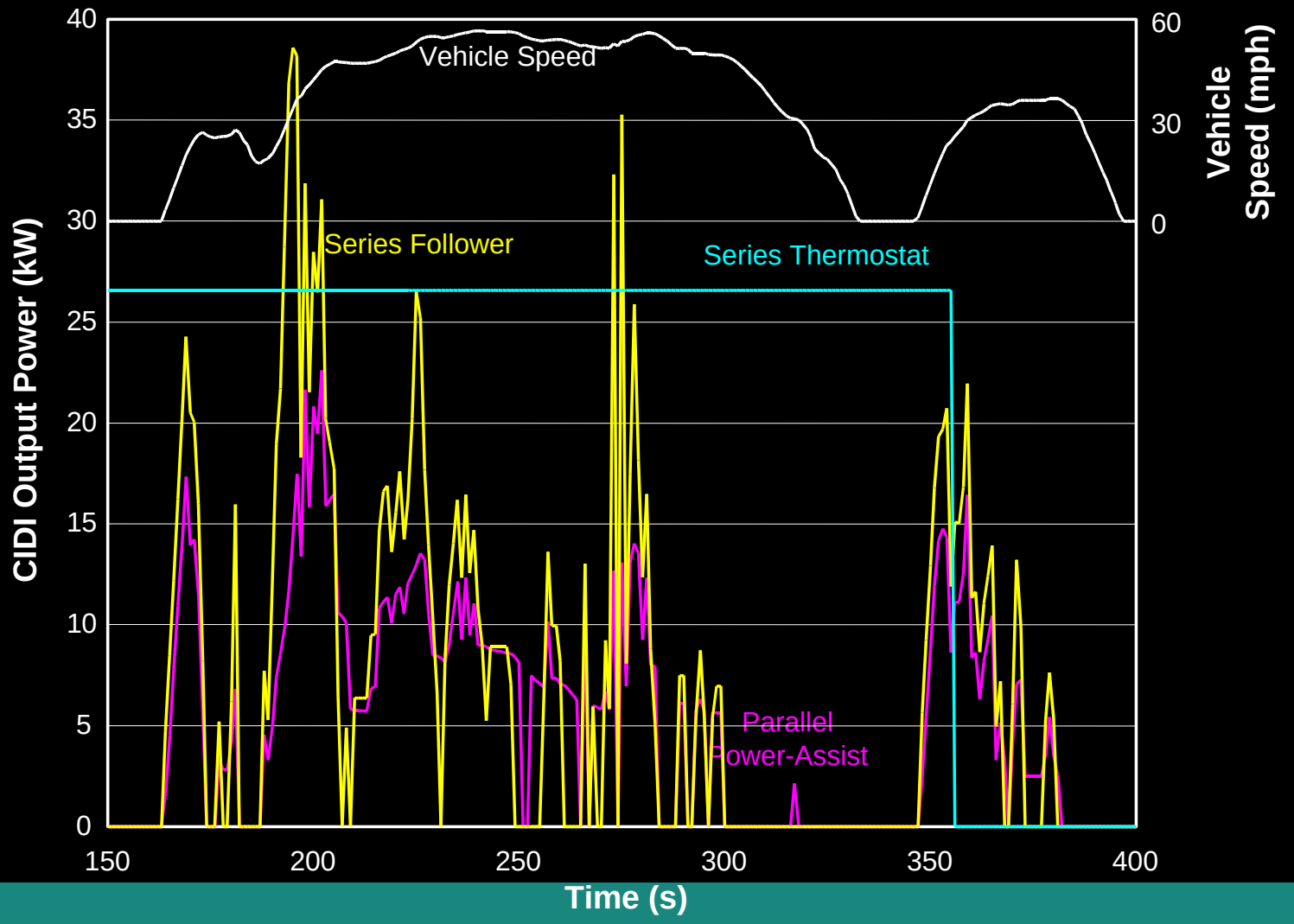




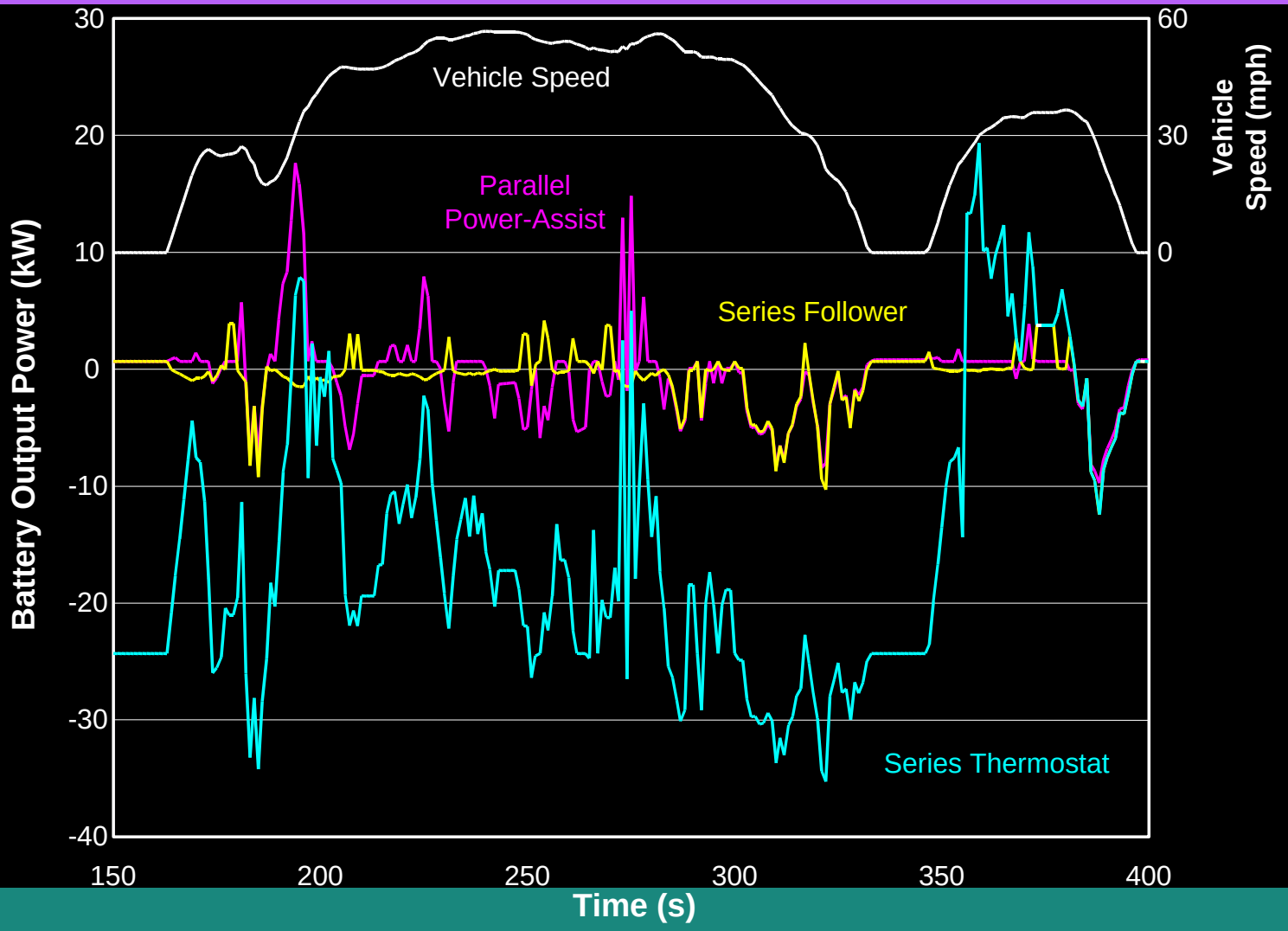




Control Strategy Comparison: Engine Power



Control Strategy Comparison: Battery Power



Application of ADVISOR: Project Examples

- PNGV technology selection
- SAE test procedure development (J1711)

Project Example #1: PNGV Technology Downselect

- *Objective* Determine most promising HEV designs
- *Timing* 2 month-long project
- *Approach*
  - Led government team to assemble vehicle assumptions
  - Worked with industry partners to verify assumptions
  - Developed a file system to automatically:
    - Specify 176 distinct vehicles
    - Size components to meet performance requirements
    - Evaluate each vehicle
    - Verify, store, and output vehicle results

Automated Configuration Evaluation Process

Control strategy
- Conventional
- Parallel
- Series
- Thermostat
- Series Follower

Engine
- CIDI
- Fuel Cell
- Gas Turbine
- SIDI
- Stirling

Battery
- Li-ion
- Pb-acid

Assemble
- Select appropriate data files
- Size components to meet performance
- Build total vehicle mass

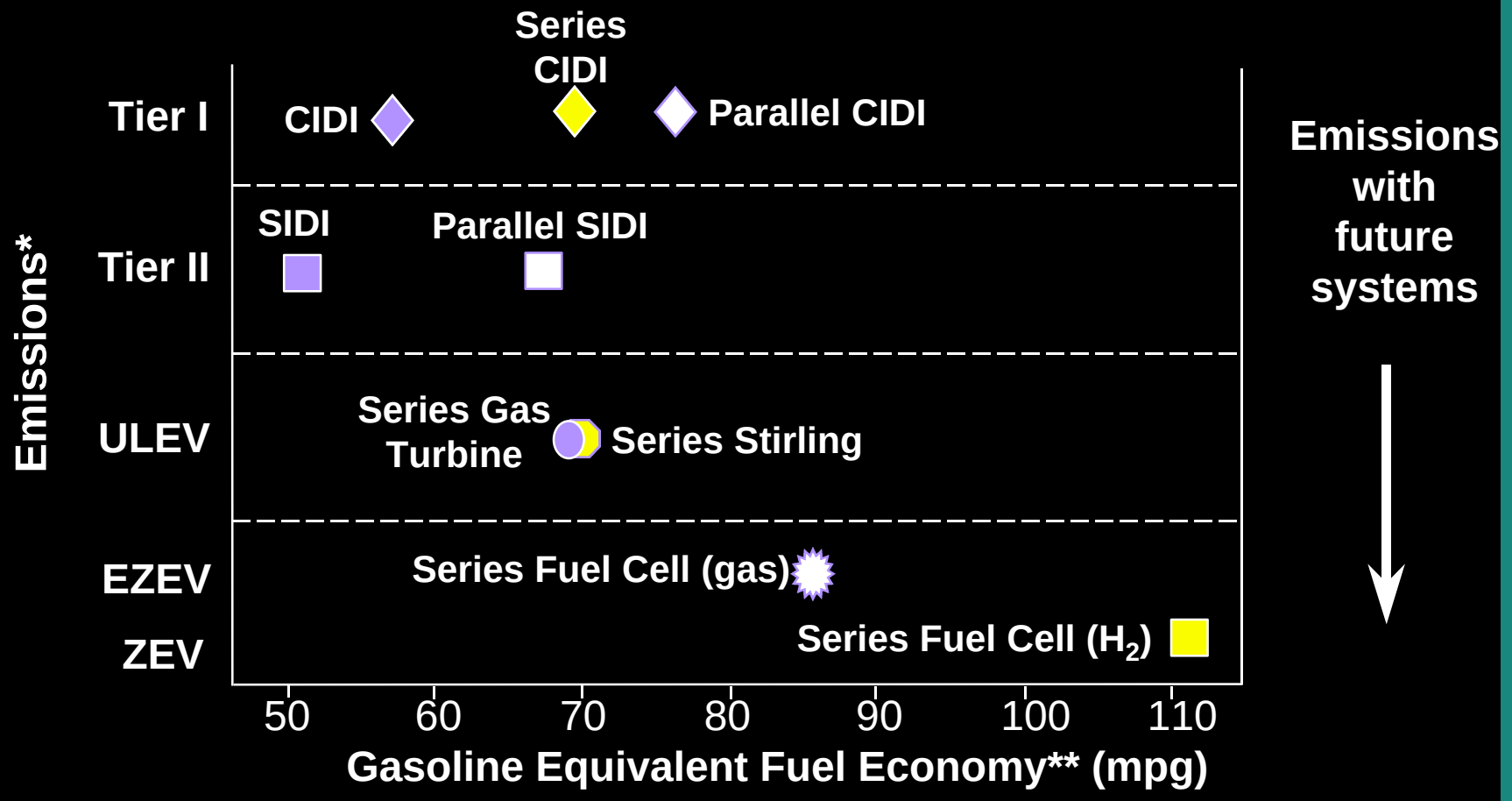
Evaluate
- Compute mpg, component ηs

Output
- Cycle-averaged mpg and ηs, diagnostics

Loop through for each vehicle configuration

SPECIFY "BUILD" & "TEST" SAVE RESULTS

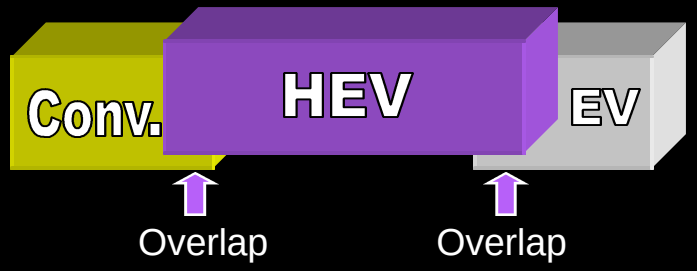
Results: Fuel Economy & Emissions



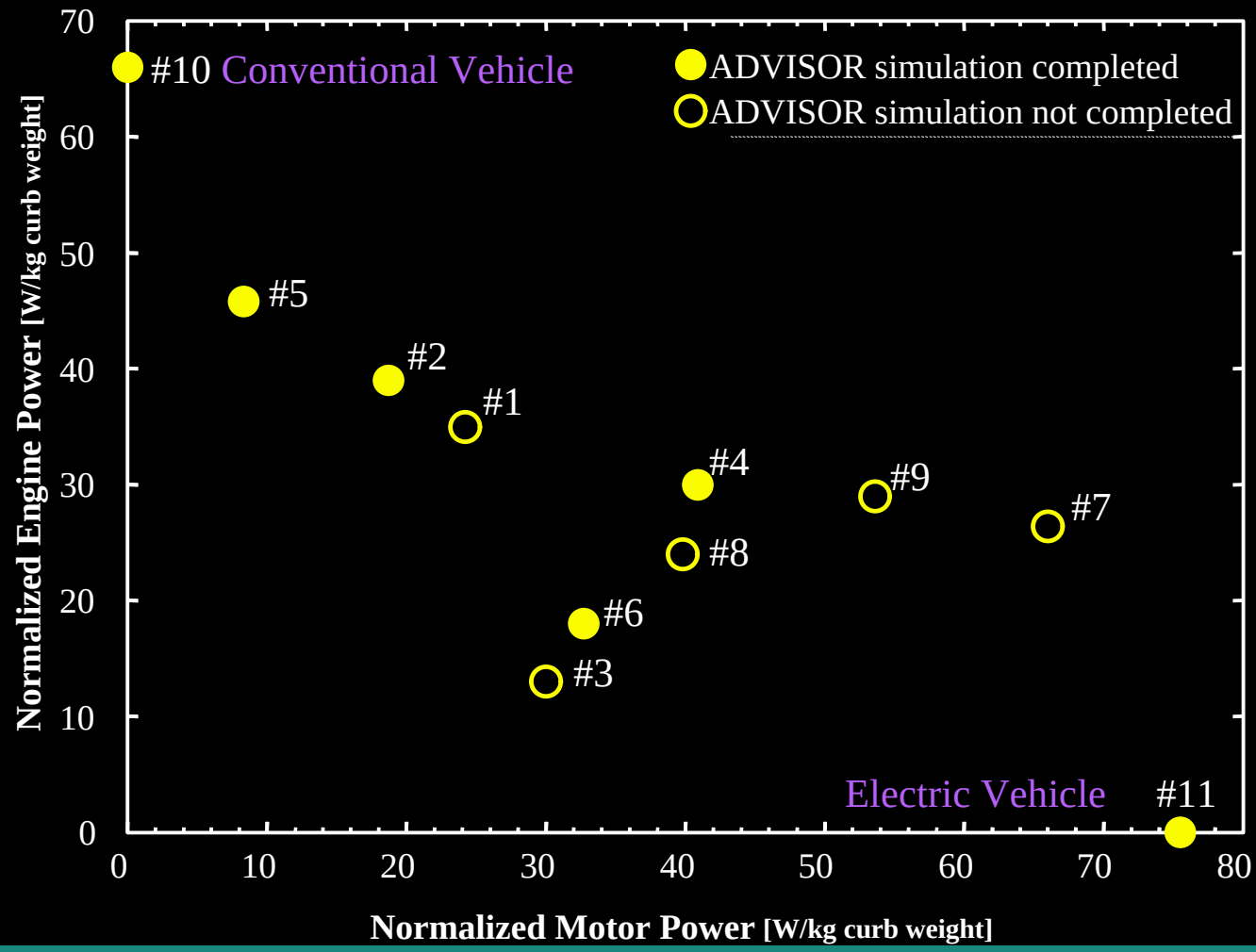
*Emissions are estimates and not from simulation results
**Fuel economy results are configuration and control strategy dependent

Project Example #2: Evaluate SAE J1711 HEV Test Procedure

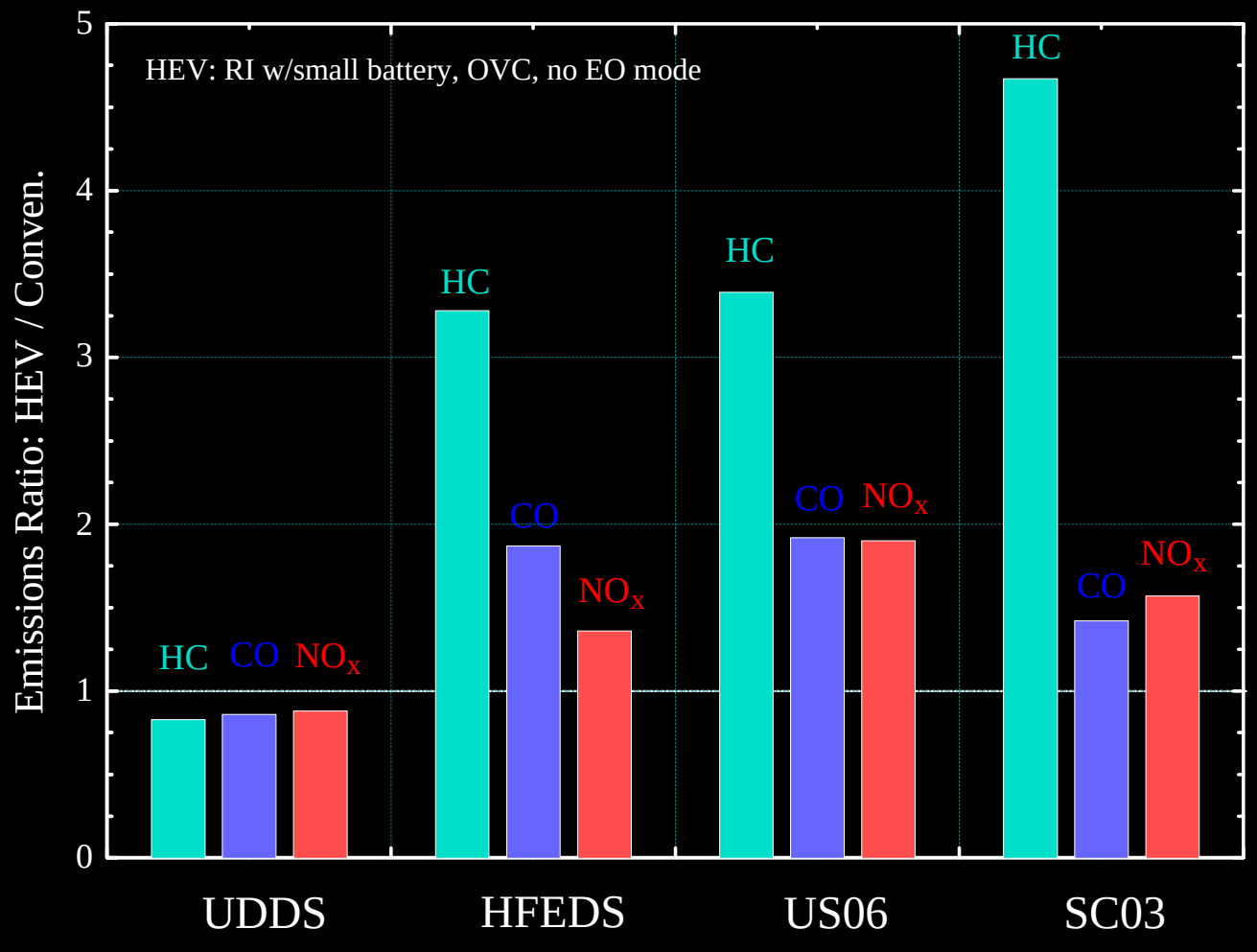
- *Objective* Evaluate draft SAE J1711 in terms of
  - robustness
  - simplicity
  - consistency with other emissions tests
- *Timing* 6 month project
- *Approach*
  - Work with SAE team to understand current J1711
  - Work with industry representatives to develop vehicle data
  - Develop file system to run vehicles through test and compute final emissions and fuel use



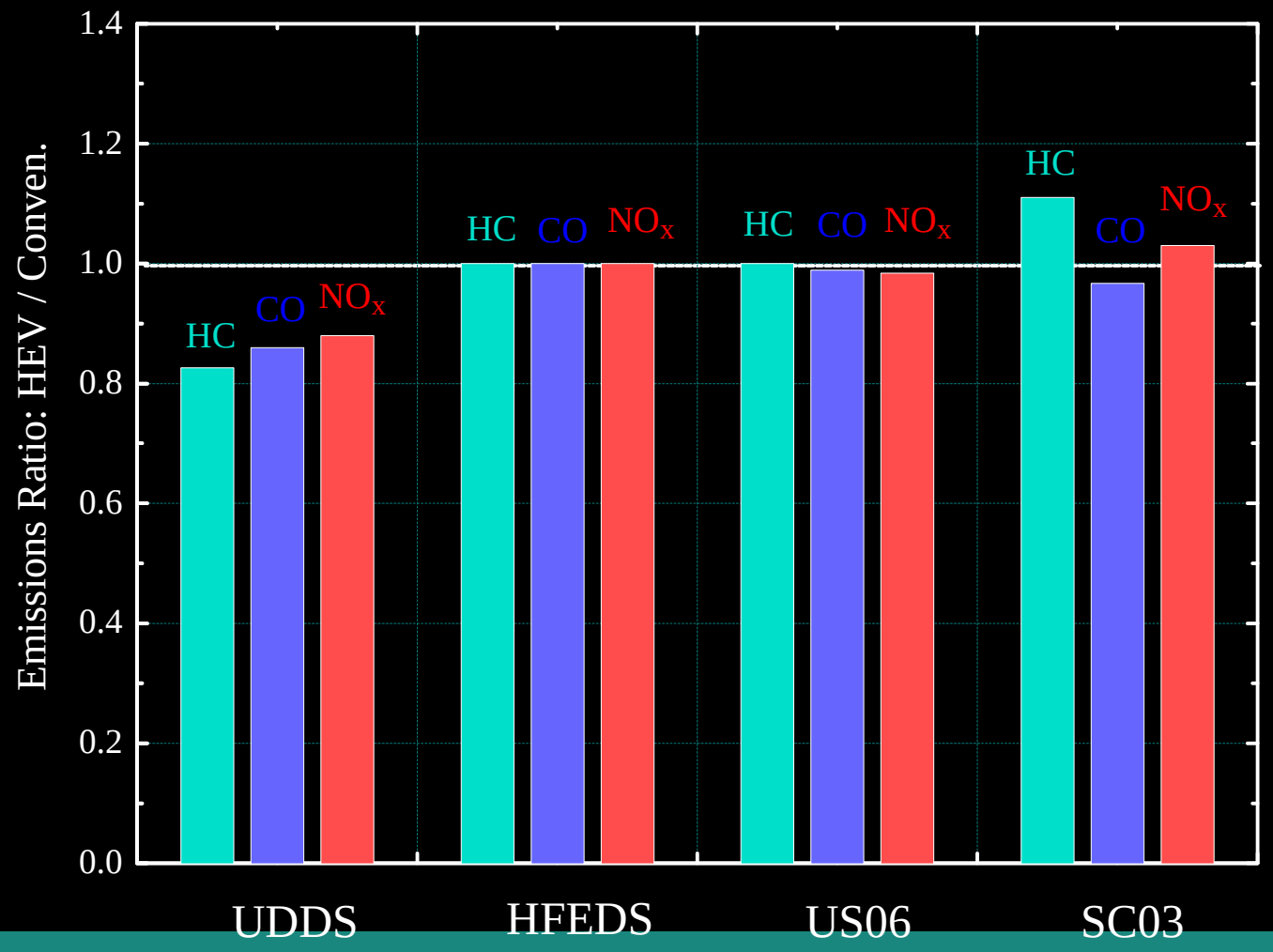
Design Space of Vehicles Considered



Emissions Predictions *BEFORE* Revisions: HEV vs. Conventional Vehicle



Emissions Predictions *AFTER* Revisions: HEV vs Conventional Vehicle



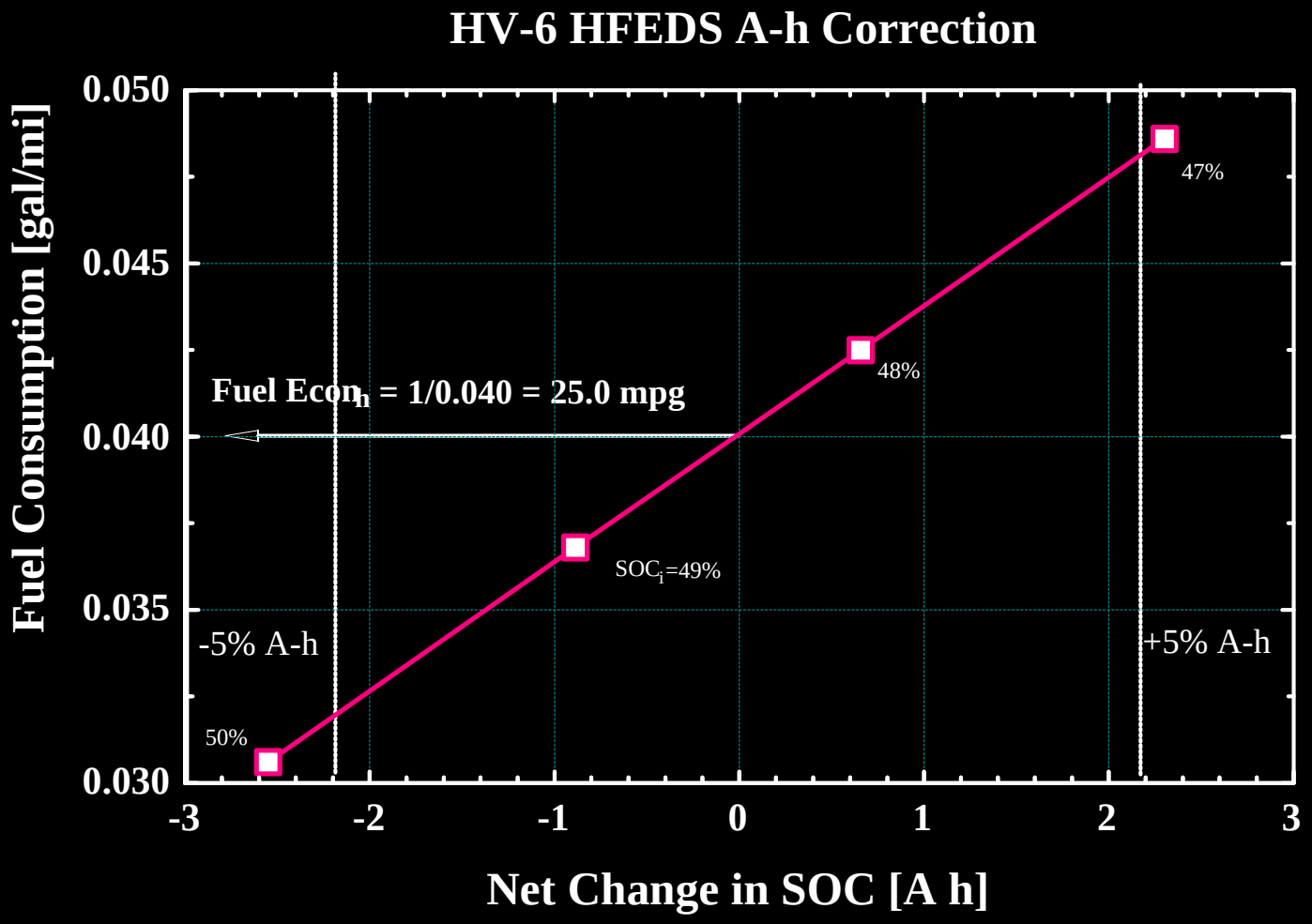
Why was ADVISOR applied to this task?

- Representative hybrid vehicles don't exist
- Required dynamometer test time extremely long
- Dynamometer time is too expensive to "try out" different test options
- ADVISOR can be used to testing vehicles and procedures "virtually"
  - saved time
  - saved money
  - highlights areas for improvement in the test procedure

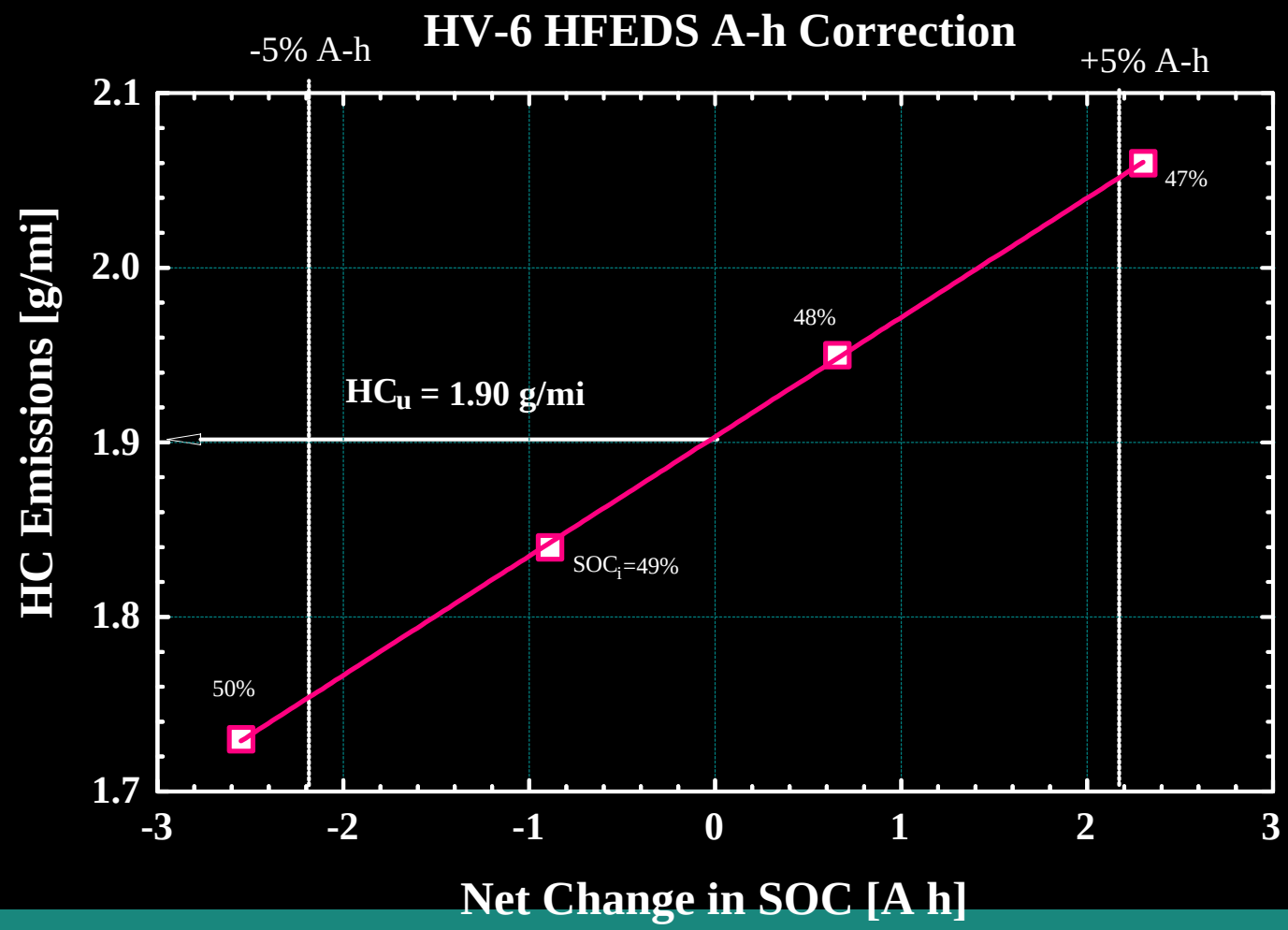
Recent Activity on SAE Test Procedure

- Investigating effect of SOC correction on:
  - Fuel Economy
  - Emissions
- SOC correction involves interpolation
- Correction is only really valid if linear relationship
  - valid for fuel economy and hot emissions
  - not accurate for cold start emissions

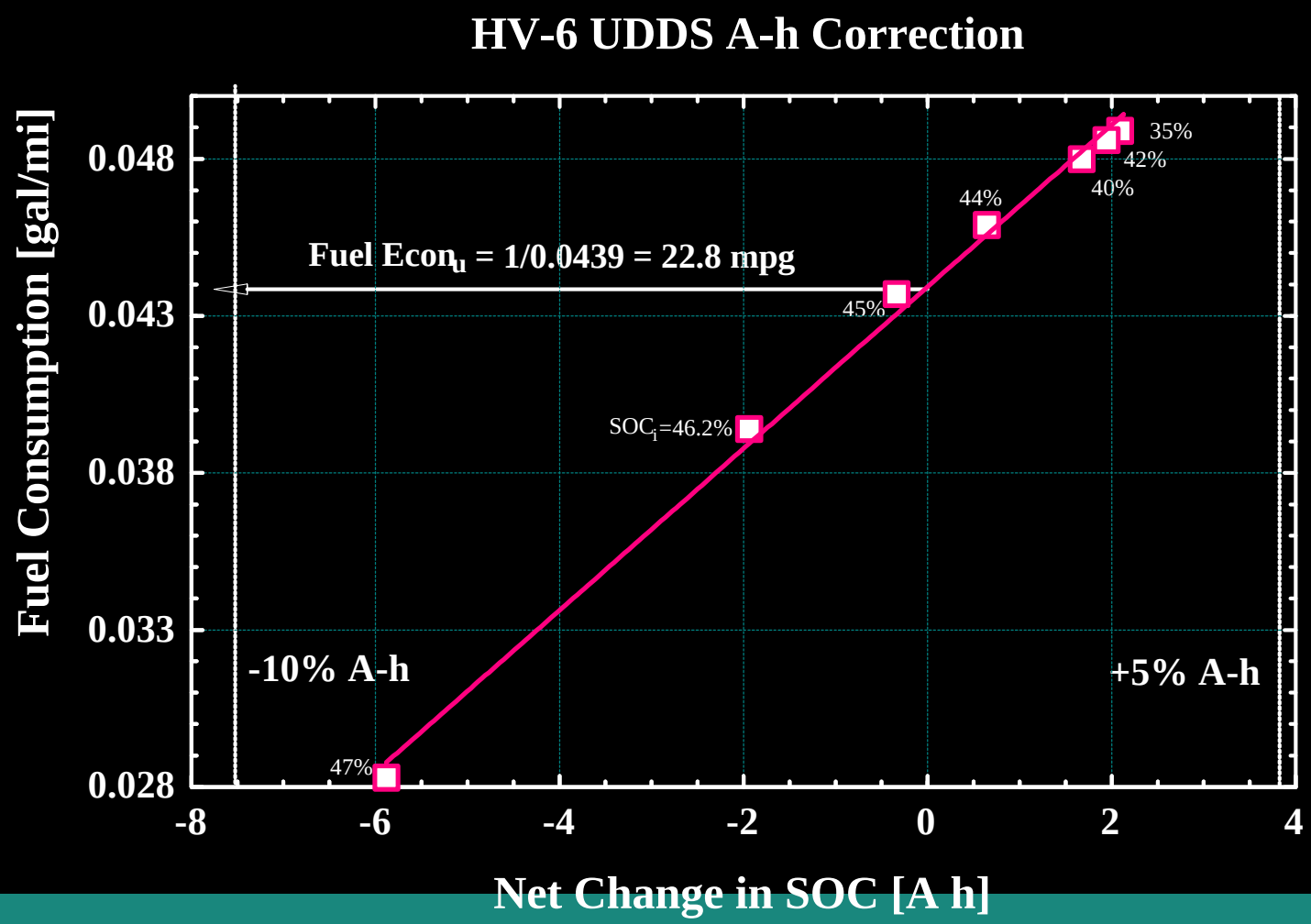
Highway Fuel Consumption Linear relationship



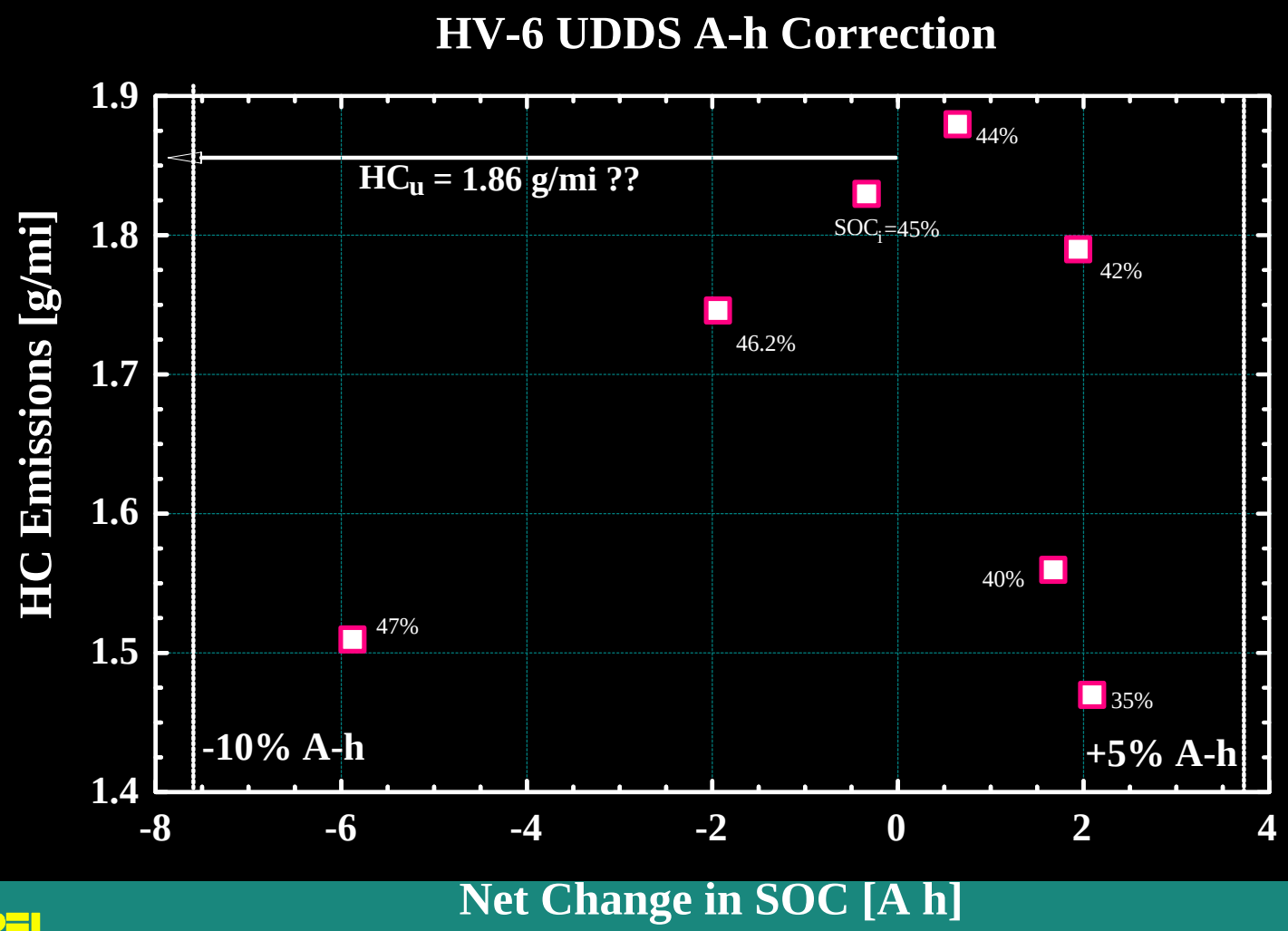
Highway Emissions
Linear relationship



Urban Fuel Consumption Linear relationship



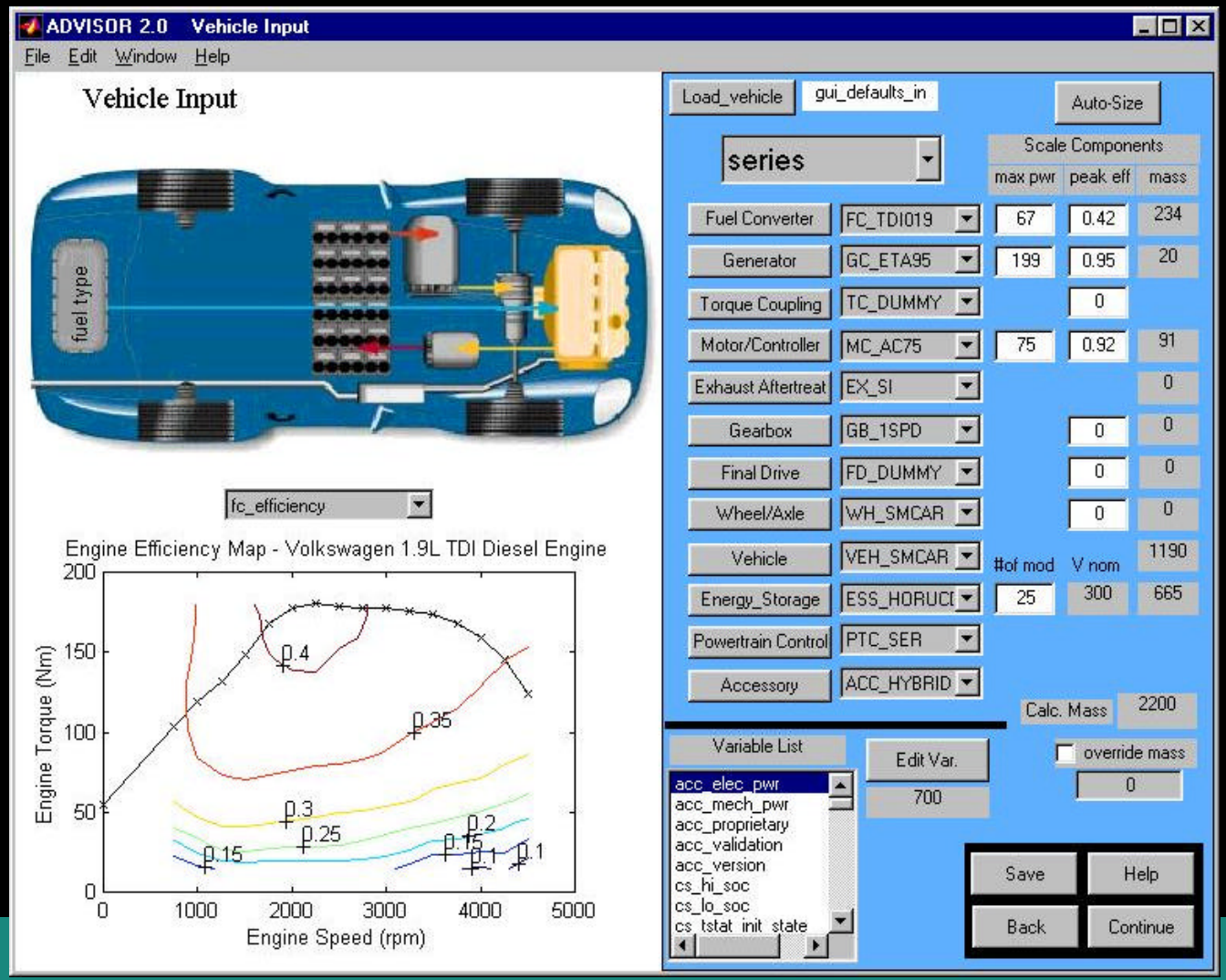
Urban Emissions
Very Non-linear relationship



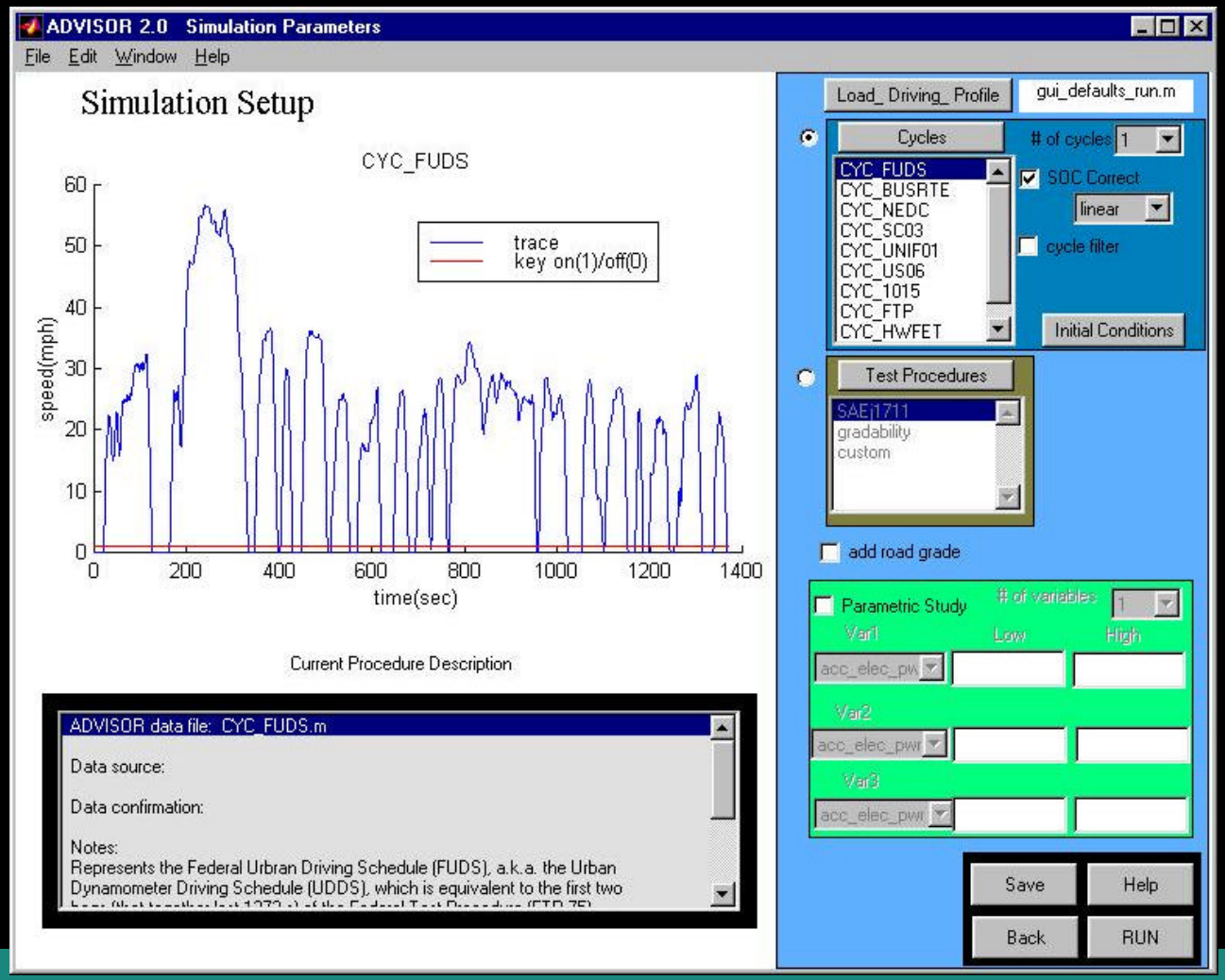
What's coming up?

- ADVISOR 2.0 release
  - planning for a September roll-out
  - publicly available software
  - will be available for free on a new web site
- New capabilities and improvements in A2
  - updated block diagrams
    - takes advantage of ML5.2/SL2.2 features
    - more intuitive structure and layout
  - new and improved GUI
    - used GUIDE to develop interface
  - full documentation included

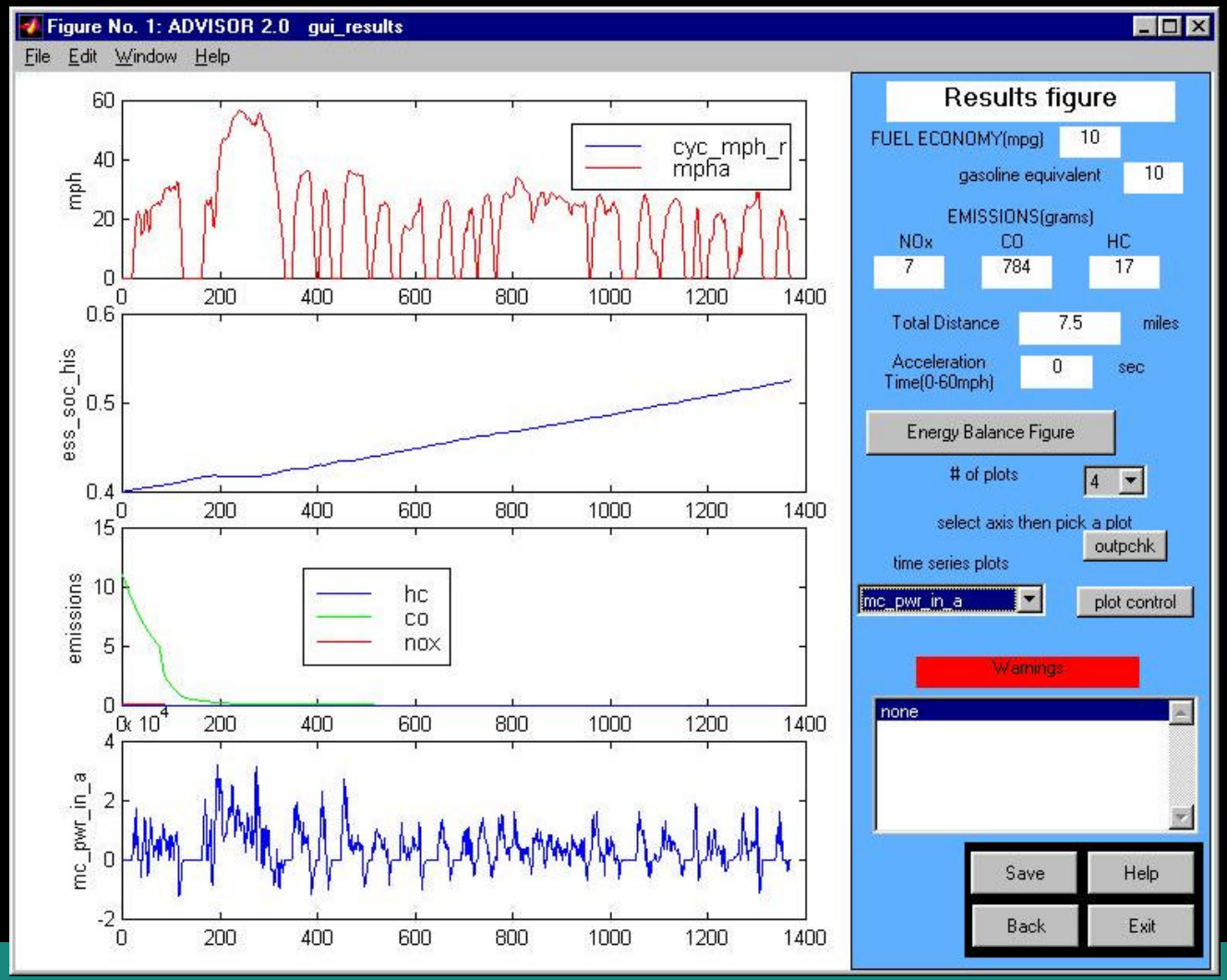
New and Improved GUI - Vehicle Input



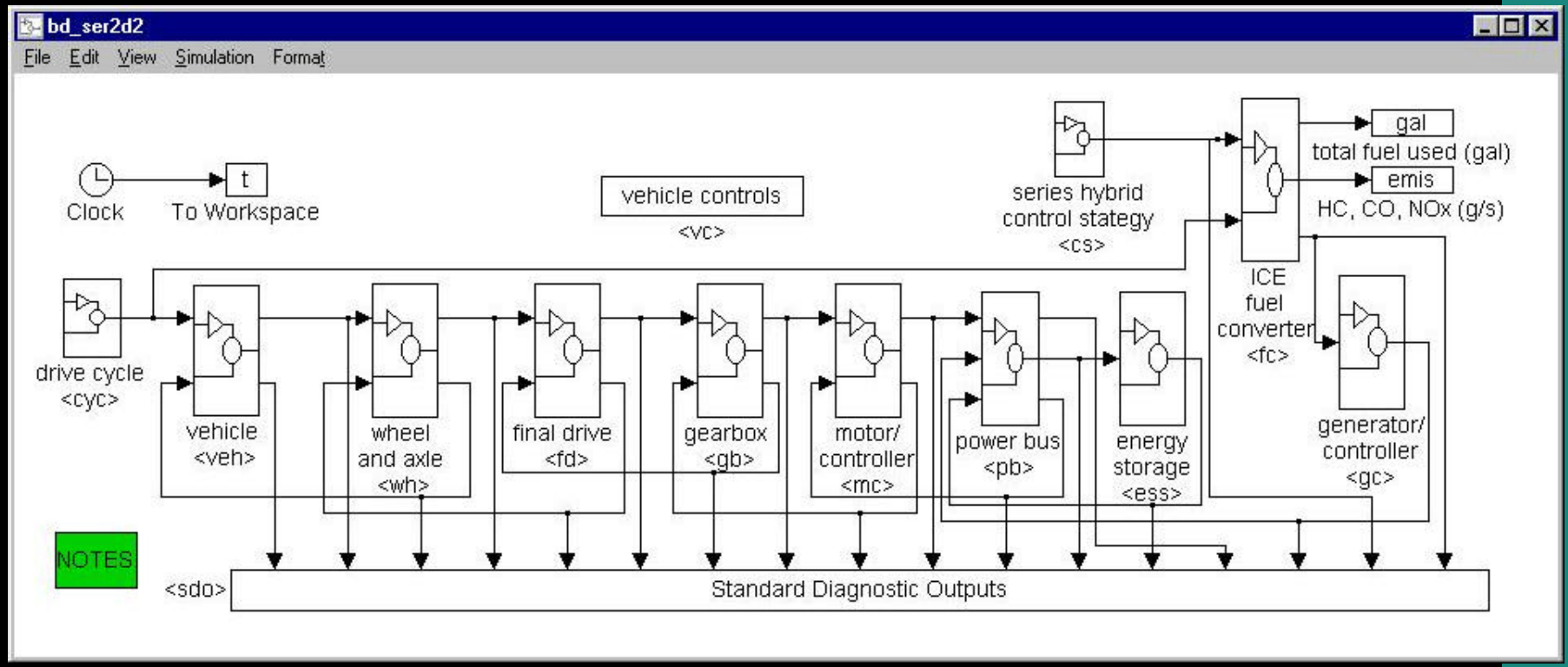
New and Improved GUI - Sim. Setup



New and Improved GUI - Results



Improved Top-Level Block Diagrams



Improved Internal Block Diagrams